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UCTION MANUAL

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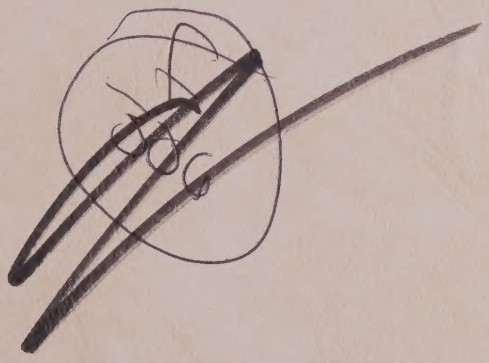
Gertsch*

MODEL FM-7

FREQUENCY METER



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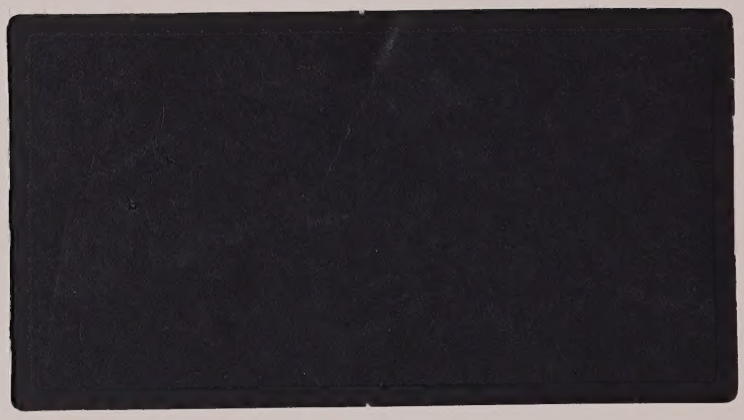

INSTRUCTION MANUAL

WARD/DAVIS ASSOCIATES
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Sunnyvale, Calif. 94086
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Gertsch*

MODEL FM-7

FREQUENCY METER

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2. Serial Number
3. Description of trouble(2)
4. Test instruments used
5. Approximate date instrument was placed in operation
6. Approximate number of hours of use
7. Has maintenance action been previously requested?
8. Other comments

Upon receipt of this information our Service Department will send you service data or shipping instructions. Upon receipt of shipping instructions forward the instrument to the factory prepaid. If requested, an estimate of charges will be made before work begins.

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Models:..... Serial No. .....

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Date..... CONDITION ON ARRIVAL.....

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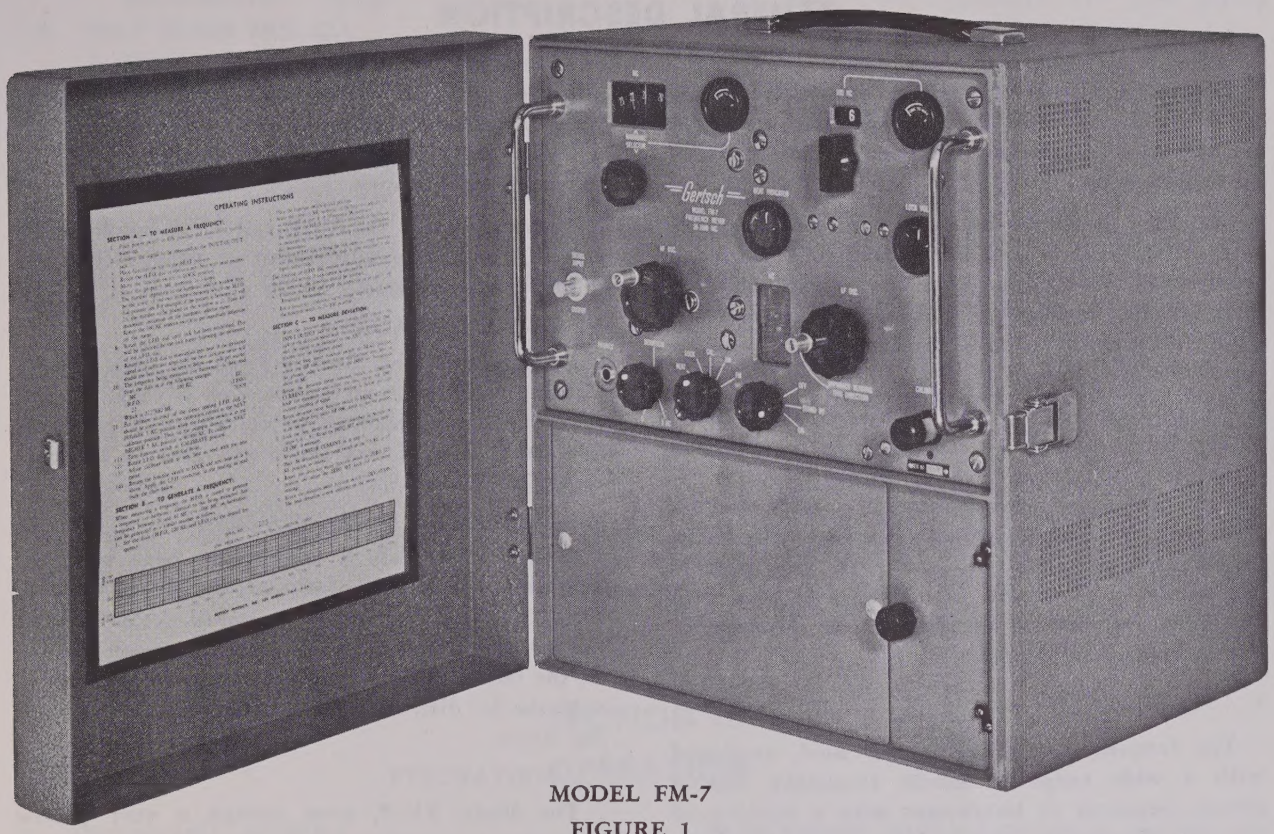
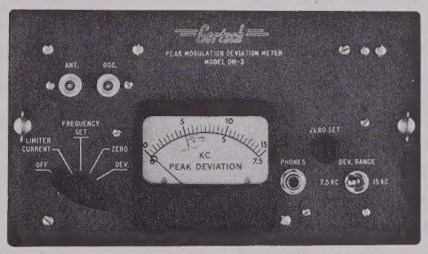

OPERATING INSTRUCTIONS
SECTION A — TO MEASURE A FREQUENCY:
SECTION B — TO GENERATE A FREQUENCY:
SECTION C — TO MEASURE DEVIATION:
Gertsch

MODEL FM-7
FIGURE 1



MODEL DM-3
FIGURE 2

SECTION I
GENERAL DESCRIPTION

This instruction book contains information on the FM-7 Frequency Meter in sufficient detail to permit the operation, adjustment and maintenance that may be encountered.

The FM-7 has been designed to provide the ultimate in ruggedness and serviceability. The unit is constructed on 5 cast aluminum compartmented chassis units mounted on a heavy aluminum front panel, plus power supply. Chassis units are easily removable for service.

The following paragraphs briefly describe features of the FM-7, however, a more detailed explanation of the theory of operation can be found in Section IV. The instrument has been designed to provide trouble-free operation and if maintenance is required, the information contained in Section V will provide the user or a component maintenance facility with sufficient information to perform all maintenance that may be encountered.

1. STABILITY

The frequency synthesis system used, combined with a wide range automatic frequency lock-in circuit, produces an instrument with a stability of ±0.0001% using the built-in 1 mc crystal standard. After "warm up", the instrument can be set to any frequency within its range and will maintain the generated frequency constantly with the above accuracies.

2. WIDE FREQUENCY RANGE

The instrument has a conservative frequency range of 20 to 1000 mc. It is a harmonic device with a fundamental range of 20-40 mc. Frequencies up to and beyond 1000 mc may be measured and generated by means of harmonics of the fundamental range; however, above 1000 mc the amplitude falls off and special techniques may be necessary. Measurements have been obtained with this instrument as high as 2400 mc. Frequencies below 20 mc can be measured (but not generated) by using a harmonic of the unknown frequency. For example, a 5 mc signal may be measured by using its fourth harmonic.

3. CALIBRATION AGAINST PRIMARY STANDARDS

The basic accuracy of the FM-7 is determined by a precise, hermetically sealed, 1 mc crystal mounted in a precision oven maintained accurately to a given temperature in the 85° C. range. Provision is made for adjusting the internal crystal frequency without removing the unit from its case.

4. FCC FREQUENCY MEASURING REQUIREMENTS

Measurement in the VHF and UHF bands to the new FCC tolerance requirement of ±0.0005% is met with a minimum safety factor of 5 to 1.

5. DIRECT READING

Frequency is read directly from the dials and indicating windows to an accuracy of .0002%. Greater accuracy may be achieved by use of the LFO calibration chart. Use of this chart will give an ultimate accuracy of .0001%.

6. SIMPLICITY OF OPERATION

In operation, only a rough zero beat with the unknown signal is required with the megacycle dial. The 100 kc dial is decade switched from 0-9 and the proper point is indicated by a maximum reading on the indicating meter. Final zero beat is obtained with the KC dial, with the aid of a zero beat indicating meter.

7. PORTABILITY

The Model FM-7, even though a very precise measuring instrument, has been specifically designed for portability. A removable metal front cover is supplied to protect dials and knobs.

The following specifications describe the characteristics of the FM-7 Frequency Meter.

A. FREQUENCY METER

1. Range:	20 MC to 1000 MC
2. Accuracy:	±0.0001% (with L.F.O. Chart) ±0.0002% (without L.F.O. Chart)
3. Resetability:	±0.00005%
4. Sensitivity:	10 mv input for 1 mw audio output
5. Beat Indicator:	Both aural and visual
6. RF Output:	a) 400 mv (fundamental range) across 50 ohms b) 400 mv 1 mc across 10K
7. Modulation:	a) Approx. 30% at 1000 cps, AM b) Approx. 1KC at 30 MC, FM (5 KC at 150 MC or 15 KC at 450 MC) (variable)

8. Power Requirements: 75 VA at 115 VAC, 60 cps

B. FM-7 (CASE MODEL)

1. Size: 13" wide x 15" high x 12" deep - max.

2. Weight: 40 lbs.

C. FM-7R (RACK MODEL)

1. Size: Standard 19" rack panel, 10½" high, 12" depth behind panel

2. Weight: 35 lbs.

SECTION II
ACCESSORIES

The following accessories are supplied with the FM-7 Frequency Meter.

1. Earphones
2. Antenna
3. Power Cord

The following accessory is available from Gertsch Products, Inc.:

1. Peak reading deviation meter, Model DM-3. The DM-3 is dual range peak reading deviation meter designed to measure deviations of 7.5 KC and 15 KC full scale. The frequency range is 20-1000 MC with an accuracy of ±5% of full scale. The mechanical design is such as to permit installation within the FM-7 case. Detailed information and specifications are available from Gertsch Products. (See Figure 1.)

SECTION III
OPERATION

1. FREQUENCY METER

The Frequency Meter FM-7 is shown in block form in Figure 7. It is essentially a frequency synthesizer.

A high frequency oscillator, tunable from 20-40 MC, is used to zero beat with the incoming unknown frequency. Harmonics of the fundamental range are used to measure frequencies from 40 to 1000 MC. Harmonics of the unknown frequency may be used to measure frequencies below 20 MC. The zero beat obtained in any case is amplified and presented both aurally and visually. Since the H.F.O. dial is calibrated in 1 MC increments, means are provided to interpolate in order to obtain the necessary resolution. The interpolating means are also used to provide AFC to stabilize the high frequency oscillator.

A stable frequency base is provided by the use of a 1 MC crystal oscillator, the stability of which is better than one part in 10^7. Harmonics of this 1 MC source are available from the 23rd to the 42nd by means of a tunable harmonic amplifier. Hetrodyne action between the output of the H.F.O. and the proper 1 MC harmonic in the first mixer produces an I.F. frequency which is always between 2 and 3 MC. The output of the 1 MC harmonic amplifier is peaked by adjusting the harmonic selector knob for a maximum meter deflection.

In the example shown a frequency of 22.17682 MC is being measured. Since the H.F.O. is oscillating at this frequency at zero beat, the 25th harmonic of the 1 MC oscillator is chosen, resulting in the 1st I.F. frequency of 2.82318 MC. The 1st I.F. amplifier is pre-tuned in 100 KC steps from 2.95 to 2.05 MC. The desired bandpass is selected by means of the 100 KC decade switch. In operation, the 100 KC switch would be rotated for maximum output on the 100 KC meter. In the example shown, position No. 1 (2.85 MC) would produce the greatest output from the 1st I.F. amplifier since the frequency of interest is 2.82318 MC.

The output of the 1 MC oscillator is divided by 10 to produce a stable 100 KC signal. Harmonics of this signal are available from 3.1 to 2.2 MC by means of the 100 KC harmonic amplifier. A harmonic is chosen such that the difference frequency between the harmonic and the output of the 1st I.F. amplifier will always be between 100 and 200 KC. In the example shown, the 30th harmonic is selected when the 100 KC decade dial is in position 1. The resulting difference frequency of 176.82 KC is amplified in a broad band amplifier and compared with a variable interpolating oscillator in a phase discriminator.

The output of the phase discriminator is an AFC

signal used to correct the H.F.O. frequency, thereby phase locking the system.

The over-all stability of the system is therefore a function of the stability of the 1 MC oscillator and the low frequency interpolating oscillator.

2. FUNCTION OF EQUIPMENT

The Model FM-7 direct reading VHF Frequency Meter will measure or generate any frequency within the range of 20-1000 mc with an accuracy of 0.0001%. It can also be used below 20 mc as described in this section.

3. READING THE DIALS

In the Model FM-7 the frequency is read directly on the dials. The H.F.O. dial will read the megacycles, the 100 KC dial the hundreds of kilocycles, and the L.F.O. dial the remaining digits (0 to 100 KC).

It is important that the dial readings correlate each other. For example, if the instrument is set to 23.999 mc. the HFO dial must be very close to 24 mc and the 100 KC and LFO dials should read 999, respectively. The 1 mc harmonic selector dial in this case should be set to 23. This is the only correct setting to obtain this instrument frequency. It may be possible that the frequency of the HFO does not agree exactly with the dial calibration. In the previous example, the HFO dial might possibly read over 24 mc but the instrument reading will still be correct if attention is paid to the reading as a whole. In this case, it obviously cannot be 24.999 mc, since the HFO dial is very close to 24 mc and the other dials 999 with the 1 mc harmonic selector dial at 23. Therefore, all dial readings must correlate each other.

4. METHOD OF OPERATION

A. TO MEASURE A FREQUENCY:

(1) Place power switch in ON position and allow 20-30 minute warm-up.

(2) Connect the signal to be measured to the INPUT - OUTPUT jack.

(3) Place function switch in the BEAT position.

(4) Rotate the H.F.O. dial to obtain a zero beat in head phones.

(5) Move the function switch to LOCK position.

(6) Select the proper 1 MC harmonic as follows: The number appearing in the harmonic selector window must be the lower of the two numbers between which the H.F.O. dial pointer lies. For example, if the pointer is between 22 and 23, the number to be placed in the window is 22. Tune for maximum indication on the harmonic selector meter.

(7) Rotate the 100 KC selector switch to get maximum deflection on the meter.

(8) Rotate the L.F.O. dial until lock has been established. This will be indicated by the lock meter following the movement of the L.F.O. dial.

(9) Rotate the L.F.O. dial to re-establish zero beat. If the measured signal is of sufficient amplitude, the beat indicator meter will enable the beat note to be seen to below one cycle per second.

(10) The frequency being measured (or harmonic) is then read from the dials as in the following example:

MC (H.F.O.)	100 KC	KC (L.F.O.)
22	1	76.820

Which is 22.17682 MC.

(11) Rotate the function switch to CALIBRATE position. Adjust the L.F.O. to the next higher 5KC point than the previous setting. In the example above this would be 80.00

(12) Adjust calibrate knob to zero beat as read with the beat meter.

(13) Return function switch to *LOCK* position. Re-establish lock if necessary by rocking H.F.O. knob until lock meter follows. Obtain final zero beat against signal being measured with the L.F.O. Read frequency as above.

(14) For ultimate accuracy of the direct reading L.F.O. dial apply the correction as read from the chart, Figure 3.

B. TO GENERATE A FREQUENCY:

When measuring a frequency the H.F.O. is caused to generate a frequency (or harmonic) identical to that being measured. Any frequency between 20 and 40 MC (to 1000 MC on harmonics) can be generated in a similar manner as follows:

(1) Set the dials (H.F.O., 100 KC and L.F.O.) to the desired frequency.

(2) Place the function switch to lock position.

(3) Select the correct 1 MC harmonic on the harmonic selector dial as explained in part 6 of "Frequency Measurement."

(4) Slowly rotate the H.F.O. dial to obtain maximum deflection on the 100 KC meter. Continue rotation until lock is established as indicated by the lock meter suddenly following the H.F.O. dial movement.

(5) Re-adjust H.F.O. dial to bring the lock meter to center position and the frequency setup on the dials is now available at the input-output jack.

The direction of H.F.O. dial rotation to obtain lock depends upon the initial dial setting. If lock cannot be obtained by a small rotation in one direction, the direction should be reversed.

(6) Calibrate the L.F.O. and apply the correction as in part 11 of "Frequency Measurement."

(7) For a frequency modulated signal repeat steps 1 thru 6 with the function switch in the FM position.

As an example in the use of the LFO curve, assume the frequency indicated on the FM-7 dials before calibration is 22.176820 MC. The LFO dials under these conditions would read 76820. The next higher CAL point is 800 as indicated on the sample curve of Figure 3. After calibration at this point the LFO dial is returned to zero beat. Due to the calibration, the zero beat may occur at a slightly different point on the LFO dial, i.e. 768.30. From the curve of Figure 3 note that the calibration curve indicates that 20 cycles must be subtracted from the fundamental frequency. The corrected frequency of the FM-7 is 22.176830 minus 20 cps, or 22.176810 MC.

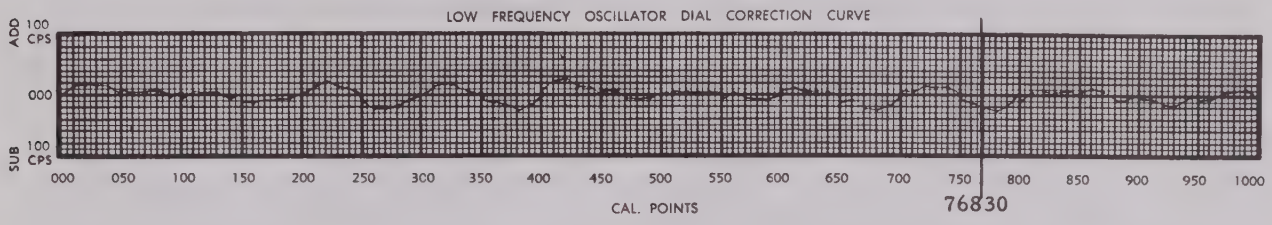


FIGURE 3

C. METHODS OF COUPLING

The method of coupling to the frequency meter depends upon the type of source being measured as well as the relative output of the source being measured. In the case of a signal from a transmitter or oscillator, sufficient coupling will be obtained in most cases with the antenna plugged into the frequency meter and using the near radiation field from the transmitter. For signal generators and other weak signal devices, direct coupling to the input-output jack via a matched coaxial line is recommended. In this manner signals may be measured throughout the entire frequency range whose voltage magnitude is at least 500 microvolts. In the case of signals considerably weaker than this, the use of an auxiliary receiver to obtain the measurement is recommended. In this case the procedure will be as follows:

(1) Locate the frequency to be measured on the receiver.

(2) Provide suitable coupling between the receiver and the frequency meter.

(3) Tune the HFO oscillator until a beat note is heard in the receiver.

(4) Change the receiver tuning slightly and note whether or not the beat note frequency changes. If the beat note frequency changes, the response is an image response or a response with a local oscillator harmonic or other type of spurious receiver response. If this is the case, continue tuning the high frequency oscillator until a proper response is obtained, that is, one in which the beat note frequency does not vary for slight receiver tuning changes.

5. ADDITIONAL NOTES ON OPERATION

(1) When the FM-7 is in the locked condition, the lock-in will hold over a reasonable range of the LFO if the lock voltage meter is reasonably centered by adjustment of the HFO dial.

(2) Accurate measurements and output frequencies will be obtained when and only when the instrument is in the "lock-in" condition.

(3) For maximum accuracy, always use the aligned double lubber line method of eliminating parallax on the LFO dial.

(4) The output of the FM-7 is normally free of spurious responses and low in incidental FM. The exception to this occurs when the 100 KC dial is on either 0 or 9 and when the LFO dial is within 10 KC of either end. When both dials are as mentioned, the residual FM increases over the normal limit of 1 cycle per megacycle of the fundamental frequency. By selecting the proper harmonic of the frequency being measured, these end points can be avoided.

(5) Under certain conditions it is possible to obtain an apparent lock with the HFO offset from its correct position. This "false lock" may be identified by two characteristics:

(a) Extremely narrow lock range.

(b) Low indication on the 100KC meter.

The dial area around a lock should always be examined to determine the proper lock condition.

6. USE AT LOWER FREQUENCIES

The frequency meter may be used for measuring frequencies below 20 mc. The only requirement is that the source being measured have sufficient output so that harmonics generated in the FM-7 fall within the fundamental, that is, 20-40 mc range of the instrument. This requirement can readily be met by most transmitters. The method of operation is

identical with the method of measuring a frequency within the range of the instrument. However, when the final frequency measurement has been made, the dial readings must be divided by the order of the harmonic being measured. For example, if the transmitter being measured has a fundamental frequency of 7.215 mc, the measurement can be made at the third harmonic, which would be 21.645 mc. When this reading of 21.645 mc has been obtained, it must be divided by 3 to obtain the transmitter frequency. The same accuracy is maintained as in the normal operating range of the instrument.

7. AUXILIARY OUTPUTS

A. The output of the 1 mc. crystal oscillator is also available at the rear for use as a secondary standard. The specifications of this output are given in the over-all specifications table.

B. The output of the low frequency interpolating oscillator (LFO) is also available at the rear of the instrument. By reading the LFO output with an external counter the LFO dial errors may be eliminated, permitting frequency measurements and generation to an accuracy and stability approaching the 1 MC time base.

8. METHOD OF DETERMINING THE FREQUENCY OF AN ENTIRELY UNKNOWN SOURCE

A. FREQUENCIES KNOWN TO BE ABOVE 20 MEGACYCLES

The method to be described requires only that the source be known to be above 20 mc. Procedure is as follows:

(1) Using the standard measuring procedure and starting at 20 mc. with the HFO, tune the HFO through the entire range and pick out the first strongest beat note against the unknown signal. Measure this frequency very carefully and call it f_1.

(2) Continue tuning upwards in frequency with the HFO until the next response having the beat note of approximately the same intensity is found. Measure this frequency and call it f_2. If only one response has been found of high signal intensity, then the frequency being measured is in the fundamental range of the instrument, that is, 20 to 40 megacycles (or 40 to 60 mc. on second harmonic if beat note falls between 20 and 30 mc.). These two cases may be distinguished by the fact that the beat note changes frequency twice as fast as the tuning of the low frequency oscillator if the response is on second harmonic.

(3) If two responses have been found, then it is obvious that the first response occurs at a frequency $nf_1 = x$ where n is some integer representing the harmonic being used and x is the unknown frequency, and similarly, since the frequency meter was tuned upwards in frequency to the next harmonic response, this response would occur at $(n-1)\ f_2 = x$ where $n-1$ indicates that the next lower harmonic of the frequency meter was being used when f_2 was measured. Solving these equations for n we obtain $n = \frac{f_2}{f_2 - f_1}$

Having substituted the actual measurements into this equation, n will come out to be very close to some integral value. Choosing the closest integral value for n, the unknown frequency is then this integer times f_1 or $x = Nf$ where N is the closest integral value to the n calculated by the equation above.

B. FREQUENCIES KNOWN TO BE BELOW 20 MEGACYCLES

(1) Starting at 20 mc., tune the HFO throughout its range and select the first loudest response. Measure this frequency carefully and call it f_1.

(2) Continue tuning upwards in frequency until the next response of approximately the same intensity has been obtained. Measure this and call it f_2. If no second response can be obtained, then the response is a second harmonic response and the frequency of the unknown would be $\frac{f_1}{2}$.

(3) If a second response was obtained, then it is obvious that the first response was obtained at a frequency $nx = f_1$, where n is an integer representing the harmonic of the source that was used in the measurement of f_1 and similarly, the second response would occur at $(n+1)\ x = f_2$ indicating that the next higher harmonic of the source was used in the second measurement. Solving these equations for n, we obtain $n = \frac{f_1}{f_2 - f_1}$. Substituting the actual measurements into this equation, n will come out to be very close to some integral value. Choosing the closest integral value to the n obtained and substituting into the equation above, we obtain $x = f_1/N$ where N is the integral value obtained above.

SECTION IV
THEORY OF OPERATION

A. The FM-7 Frequency Meter employs unit construction to simplify testing and maintenance. The following units are assembled to perform the functions outlined in section III.

Unit 1 — H.F.O. Chassis

Unit 2 — 100 KC Step Chassis

Unit 3 — Phase Discriminator Chassis

Unit 4 — L.F.O. Chassis

Unit 5 — Crystal Chassis

Unit 6 — Power Supply Chassis

Unit 7 — Front Panel and Cable Harness

B. DETAILED DESCRIPTION

1. HIGH FREQUENCY OSCILLATOR AND 1 MC HARMONIC AMPLIFIER

The H.F.O. (V104) is a Hartley E. C. O., continuously variable from 20 mc to 40 mc by capacitor C118A.

A voltage sensitive silicon capacitor (CRC101), across the tank circuit provides automatic frequency control when the oscillator is locked to the L.F.O.

The A.F.C. voltage on the lock line controls the bias on CRC101 which determines its effective reactance as presented to the tank circuit. The potentiometer R114 is geared to the main tuning capacitor shaft to automatically reduce the A.F.C. voltage proportional to capacitor rotation. This produces an approximately equal locking range throughout the H.F.O. tuning range.

V105 is the buffer-output amplifier and the RF output is from the secondary of the tuned transformer T103 through J104 to the mixer-detector board in the audio chassis and from there to the input-output jack J701 on the front panel. The screen voltage for V105 is obtained from the audio chassis where it is caused to vary at a 1 KC rate when the function switch is in the AM modulation position, thus amplitude modulating the RF output.

The 1 mc harmonic generator V101, supplies two outputs when driven with a 1 mc signal. The output from the secondary of the tuned transformer T101 in the suppressor grid circuit is used to drive the decade divider V201 in the 100 KC chassis.

The plate signal, a 1 mc pulse of high harmonic content, is fed to the synchronously tuned harmonic selector V102 (and amplifier V103) from which the 23rd to 42nd harmonics are selected by the tuning capacitor C107.

The capacitor shaft of C107 is coaxial with that of C118 and a 1 mc harmonic selector control knob is located on the front panel. A coupling between the two shafts is provided such that the harmonic selector (C107) is carried to approximately the correct setting by the H.F.O. tuning capacitor C118, yet allowing an incremental adjustment to maximize the correct harmonic output.

The proper harmonic number (as explained in the operating instructions) when caused to appear in the harmonic selector window must be adjusted for maximum output as indicated by meter M701, which measures the rectified 1 mc harmonic signal appearing in the 100 KC chassis on the grid of the mixer tube V201.

The number appearing in the harmonic selector window is not the actual harmonic but is offset by 3 for simplicity of operation. The harmonic to be used is that which when mixed with the H.F.O. frequency will produce an intermediate frequency between 2 and 3 mc.

The harmonic output is taken from the secondary of the tuned transformer T102 through J103 and mixed with the H.F.O. output from J105 in the 100KC chassis.

2. 100 KC SELECTOR CHASSIS

The plate circuits of the mixer tube V204 and the I.F. amplifier V205 are synchronously tuned by switch sections C and D of 201, over the frequency range of 3-2 mc in ten 100 KC wide steps. The switch consecutively adds the trimmer capacitors in parallel to cover this range.

One of the ten switch positions will pass the intermediate frequency produced by the mixing of the H.F.O. and the properly selected 1 mc harmonic. The number of the switch position (appearing in the window on the front panel) will be the hundreds of kilocycles of the measured or generated frequency.

The 4 gang switch S201 when rotated to the passband that accepts the intermediate frequency, automatically selects the correct 100 KC harmonic to be mixed with the output of V205 in the mixer V301 of the phase discriminator chassis.

The decade divider V201 has an input of 1 mc (from an output of V101) and provides an output of 100 KC. The 100 KC pulse appearing in the plate circuit is differentiated and the resultant positive going pulse applied through the biased diode network CR202 and CR203 to the harmonic selector tuned grid circuit of the regenerative cathode follower V202. Switch sections S201A and S201B synchronously tuned the grid and plate circuits in 10 steps to

select and amplify the 31st through the 22nd harmonic of the 100 KC pulse.

A second output from the cathode of V201 through R202 is the input to the 10 KC decade divider (V303) in the phase discriminator chassis.

Diode CR207, in the second control grid of V204, rectifies a portion of the 1 mc harmonic and the DC current through R220 to meter M701 indicates the proper adjustment of the 1 mc harmonic selector.

3. PHASE DISCRIMINATOR CHASSIS

The Phase Discriminator Chassis performs a number of functions. Mixer tube V301 receives two inputs from the 100 KC selector chassis. The proper 100 KC harmonic is fed to grid#1 and the I.F. signal from V205 is fed to grid #3. The phase discriminator I.F. amplifier (V302) selects and amplifies the proper mixer product from V301 (a freqency between 100 and 200 KC.) This signal is applied to the diode phase discriminator through coupling condenser C316. The comparison frequency for the phase discriminator comes from the L.F.O. through the cathode follower, phase splitter (V304) and push-pull driver (V305).

The decade divider (V303) receives 100 KC from the cathode of V201. The 10 KC pulse in the plate circuit of V303 is differentiated and the resultant 10 KC spike is applied to the calibration detector CR304. The calibration detector also receives input from the L.F.O. cathode follower (V304). The output of CR304 is fed to the audio amplifier through the function switch. When the function switch is in the CAL. position this output is amplified and fed to the BEAT indicator and earphones.

4. LOW FREQUENCY OSCILLATOR

The accuracy of any reading taken with the FM-7 is dependent upon the tracking, stability, and drift of the low frequency interpolation oscillator. Excessive dust or dirt could introduce enough error to render this unit useless. Care must be observed when removing the FM-7 from the cabinet not to set the unit in such a manner that the L.F.O. will rest on any object, such as a screwdriver on the bench. Almost every component in the L.F.O. has been chosen to contribute to the over-all stability of the oscillator. Many of these components have been chosen to have other than a zero temperature coefficient. It is therefore a requirement that, in the event of replacement, any parts should be replaced with exact factory duplicates.

The L.F.O. consists of a modified Hartley oscillator with enough feedback to barely sustain oscillation over the required tuning range. This tuning range is from 100 to 200 kcs. while the dial reads from 00.00 kcs. to 100.00 kcs. The ouput is taken from the cathode tap on the coil through a large decoupling resistor R407. This output feeds a cathode follower V304 in the phase discriminator.

5. CRYSTAL OSCILLATOR AND AUDIO CHASSIS

A. CRYSTAL OSCILLATOR

Tube V504 is the crystal oscillator and V503 the buffer amplifier. The signal at the plate of V503 is rectified negative by CR503 and a portion of the DC voltage used as a bias on the crystal oscillator tube for automatic gain control. R523 controls the gain of V503 which determines the amount of a. g. c. developed versus crystal activity. R523 is adjusted to have a voltage of 0.6 V peak to peak at pin No. 1 of V504. C528 and C532 were selected such that when C530 and C531 are in approximately their mid-range, the crystal will resonate at one megacycle $\pm$.1 ppm. Sufficient adjustment remains to compensate for aging effects of the crystal.

In the event C530 and C531 approach minimum without the correct frequency, capacitors C536 thru C539 may be removed from the circuit by clipping out jumper wires in the following sequence: brown, red, orange, yellow. Remove only one jumper at a time and retune C530 and C531 until the correct frequency is obtained. Each capacitor, C536 thru C539 is 33 PF, which is a smaller value than the parallel trimmers, thereby providing adequate overlap. In the event a replacement crystal requires more capacity, simply replace the jumpers in the reverse sequence.

Transformer T502 supplies a low impedance output of approximately 1.5V RMS to the H.F.O. chassis. In any position of the switch (S501) the 1 mc output is available at J702.

The crystal oven has a 117 V. A. C. heater and is not interrupted by the standby switch. Standby position also holds the filaments of all tubes on.

B. AUDIO SECTION

The audio section contains the mixer-detector board, function switch, two stages of audio voltage amplification (V501), cathode follower (V502A), power output stage (V502B) and a lock voltage VTVM (V505).

The output of the H.F.O. at J503 is applied to the harmonic generating diode CR501, and the signal is then mixed with the frequency present at J502 (input-output) and the beat note detected by diode CR502. The beat note is then fed to the beat note amplifier by the function switch (S501) in the beat and lock positions.

The beat note, after amplification by V501, is direct coupled to the first half of V502, a cathode follower. The beat note signal present at the cathode

is then capacity coupled to the beat indicator meter M705 which will visually indicate the beat note signal to far below the audible range.

The reduced signal at the junction of R512 and R513 is capacity coupled to drive the audio output stage V502B.

The function switch (S501), when in the AM or FM position, converts the output stage to a tuned-grid tuned-plate oscillator.

The lock position of the function switch is identical to the beat position except that the short to ground on the lock line is removed by S501H and the 1 MC crystal frequency is fed to the H.F.O. V505, the lock voltage VTVM will now indicate the amount and polarity of the A.F.C. voltage present to maintain the correct frequency of the H.F.O.; control R547 is used to adjust the meter to center position when the function switch is in any but lock or FM position.

C. FREQUENCY MODULATION

In the FM MOD position of the Function Switch V502 is converted from an amplifier to an oscillator. The output of the oscillator adds an AC component to the DC lock line voltage, causing the HFO to deviate from its center frequency.

The AC signal is fed to the lock line through R530, R531, R529, C524 and R528, a series RC circuit. R531 is a trim pot adjustment to provide approximately 1KC deviation at fundamental frequencies (20 - 40 mc) when the Front Panel Deviation Control, R529, is fully clockwise.

6. POWER SUPPLY

Plate and heater power (except crystal oven) for the FM-7 is provided by a single power transformer T601.

The 220 V A.C. from the secondary winding is rectified by four silicon rectifiers in a full wave bridge circuit.

Standby switch S701 interrupts the 220 V A.C. to the bridge rectifier but allows all tube heaters and the crystal oven heater circuit to operate normally.

The D.C. voltage (+150 V nominal) furnished by the power supply is regulated. A gas diode V603 is the reference source and the V602 is the D.C. amplifier. The series regulator V601 is shunted by R601 to reduce the amount of load current through it.

The regulation is necessary primarily to reduce the internal impedance of the supply preventing the low frequency beat note from being coupled to the other circuits in the FM-7. R610 is adjusted to set the B+ voltage to 150 V ±1.5 V.

SECTION V
MAINTENANCE

1. SELF CHECKING AND ALIGNMENT

The FM-7 possesses many self checking features and it is possible to correct almost all minor misalignment due to tube changes, aging of components etc., without the need of additional test equipment.

A. HIGH FREQUENCY OSCILLATOR

(1) Remove the 1 mc harmonic output tube (V103).

(2) Connect a short coaxial cable between the 1 mc output and the INPUT-OUTPUT jack.

(3) Connect a short clip lead across the 10K resistor that is in series with the 1 mc output jack.

(4) Rotate the H.F.O. dial and beat note will be heard at every megacycle point.

(5) If dial tracking is off, adjust C120 and C130 at the 40 mc end and L103 and T103 at the 20 mc point.

(6) Replace V103 and set the 100 KC selector dial to zero.

(7) Set the 1 mc HARMONIC SELECTOR dial to 38 and the H.F.O. dial to 38 mc and rotate slightly to get maximum reading on the 100 KC selector meter.

(8) Adjust C130 to get a maximum 100 KC selector meter reading.

(9) Set the 1 mc HARMONIC SELECTOR dial to 22 and the H.F.O. dial to 22 mc as in step 6.

(10) Adjust T103 to get a maximum 100 KC selector meter reading.

B. 1 MC HARMONIC SELECTOR

With the 100 KC selector switch set at 5 and the H.F.O. dial set to approximately 22.5 mc, the 1 mc harmonic selector should cause a peak reading on the harmonic selector meter and 100 KC selector meter when the number 22 is centered in the window. Peak meter readings should also be obtained when the H.F.O. is set to 38.5 mc and the 1 mc harmonic has the number 38 centered. If the centering is off enough to warrant it, the following procedure can be used for re-alignment.

(1) Set the H.F.O. dial to 38.5 mc and center the number 38 in the 1 mc HARMONIC selector window.

(2) Set 100 KC selector dial to 5.

(3) Adjust C108 and C114 to give maximum reading on the 1 mc HARMONIC selector meter. This should also produce a maximum reading on the 100 KC selector dial, which insures the correct harmonic has been chosen.

(4) Set H.F.O. dial to 22.5 mc and the 1 mc HARMONIC selector to center the number 22 in the window.

(5) Adjust L102 and T102 for maximum reading on the meters as in Step 3.

(6) Repeat Steps 1 through 5, if necessary.

C. 100 KC SELECTOR CHASSIS

1. 100 KC SELECTOR I.F.

Set up and lock a frequency of 30.095 mc as per operating instructions. As the L.F.O. is rotated from 0 through 100, the 100 KC selector meter reading will indicate the bandpass of position zero of the 100 KC chassis I.F. The bandpass should be essentially symmetrical. Each 100 KC passband (positions 0-9) can be checked in this manner. If the bandpasses are too unsymmetrical, they can be re-aligned as in the following:

(1) Set up and lock the FM-7 to generate a frequency of 30.055 mc.

(2) Adjust the two I.F. trimmer capacitors marked 0, in the two groups of trimmers nearest the front panel, to give a maximum 100 KC selector meter reading.

(3) Reset the 100 KC selector switch to 1 and re-establish lock.

(4) Adjust the I.F. trimmer capacitors marked 1 as in Step 2.

(5) Continue to adjust each set of I.F. trimmers 0 through 9 in this order, as in Steps 2, 3, and 4.

2. 100 KC SELECTOR HARMONICS

(1) Set up and lock a frequency of 30.050 mc on the FM-7.

(2) Adjust the two 100 KC harmonic selector trimmer capacitors marked 0 in the two groups of trimmers toward the rear of the chassis for a maximum output as viewed with a scope at test point TP203.

(3) Change the 100 KC selector switch to position 1 and adjust the H.F.O. to re-establish lock.

(4) Adjust the two 100 KC harmonic selector trimmer capacitors marked 1 as in step 2.

(5) Continue to adjust each set of trimmers, 0 through 9, and in that order, as in Steps 2, 3 and 4.

D. PHASE DISCRIMINATOR CHASSIS

1. 100-200 KC I.F. AMPLIFIER

To check the response or to re-align the I.F. amplifier in the phase discriminator chassis, the following procedure should be followed:

(1) Remove connections to J301 and J302.

(2) Inject a 52KC signal into J301 and observe the waveform at test point TP302. Adjust the level of the signal generator to prevent limiting in the amplifier.

(3) Adjust L301 for minimum signal at TP302.

(4) Change the signal generator frequency to 300KC and adjust L302 for minimum signal at TP302.

(5) Re-connect cabling to J301 and J302.

E. LOW FREQUENCY OSCILLATOR

The accuracy and stability of the FM-7 is primarily dependent upon the low frequency interpolating oscillator (L.F.O.). Under no conditions should a properly functioning L.F.O. be tampered with. Proper operation of the L.F.O. will be indicated by a variable 100 to 200KC signal at test point TP305. The amplitude of this signal will normally be between 0.5 to 1.0 V RMS. Should a tube or component change be required, the end points of the L.F.O. dial should be checked and set if necessary. The procedure is as follows:

(1) Rotate the FUNCTION switch to the CAL position.

(2) Set the L.F.O. dial to its maximum indication of 100. Adjust the CAL control for a zero beat as indicated on the beat meter.

(3) Set the L.F.O. dial to 000 and adjust L401 for a zero beat.

(4) Repeat Steps 2 and 3 until both end points of the L.F.O. dial result in a zero beat.

CAUTION: Do not make any adjustment on the L.F.O. variable capacitor, C401.

F. 1 MC CALIBRATION

The B.N.C. connector labeled 1 MC OUTPUT is the output from the internal 1 mc crystal oscillator and is present at all times.

To adjust the frequency of the 1 mc crystal oscillator a snap-out plug on the left side of the FM-7 case gives access to the trimmer capacitors from the outside.

The preferred method of adjusting the frequency is by comparison to a secondary standard with a Lissajous pattern or using the 1 mc output as a

sync for an oscilloscope. An audible beat note type of adjustment will not give the required accuracy. Either one or both of the trimmer capacitors may be adjusted to stop the oscilloscope pattern.

The crystal oscillator should not be adjusted until after at least a one hour warm up period.

A method of calibrating the 1 mc crystal oscillator to WWV, using a communications receiver is as follows:

Tune the receiver to WWV on either 15 mc or 20 mc. Couple the FM-7 1 mc crystal output (J507) through a 5-25 uuf trimmer capacitor to the receiver antenna connector. Adjust the trimmer capacitor to get the maximum beat note amplitude as indicated by the S meter. An alternate beat note indicator can be an oscilloscope very slightly coupled (1 or 2 uuf) to the receiver 2nd I.F.

The 1 mc crystal oscillator trimmer capacitors can then be adjusted to the lowest observable beat note frequency.

A beat note frequency of one cycle per second, (timed with a watch) will give a comparison accuracy of 5 parts in 10^8 if the receiver is tuned to 20 mc or 6.67 parts in 10^8 if tuned to 15 mc.

G. PROCEDURE FOR CHECKING BOTH 100KC AND 10KC DECADE DIVIDERS

This instrument contains two frequency dividers which may require periodic adjustment for proper performance.

NOTE

INDICATION OF DIVIDER MALFUNCTION IS THE INABILITY TO HEAR CLEAN CALIBRATION ZERO BEATS IN HEADPHONES IN THE "CAL" POSITION.

ZERO BEATS SHOULD OCCUR EVERY 5KC ON THE LFO DIAL.

Before making adjustments allow a 1 hr. warm-up period.

DIVIDER ADJUSTMENTS

(1) Short TP305 to chassis. (Item 1, Fig. 6).

(2) Connect 1 MC OUTPUT (Item 2, Fig. 4) to test point TP304 (Item 3, Fig. 6). A clip lead or wire will suffice.

(3) Set Function Switch to CAL position.

(4) Set LFO to 100,000. Adjust CAL control for zero beat as indicated by BEAT METER.

(5) Off-set LFO so that an audible tone of approximately 300 cps is heard in headphones.

(6) Remove connection of step 2 and connect TP303 (Item 4, Fig. 6) to TP304 (Item 3, Fig. 6).

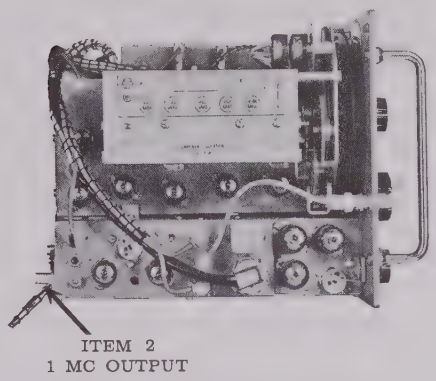


FIGURE 4 (LEFT SIDE VIEW)

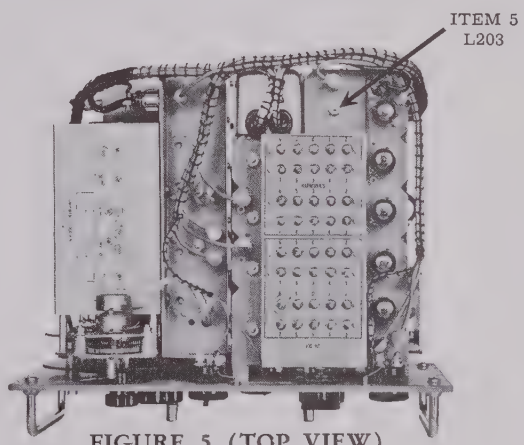


FIGURE 5 (TOP VIEW)

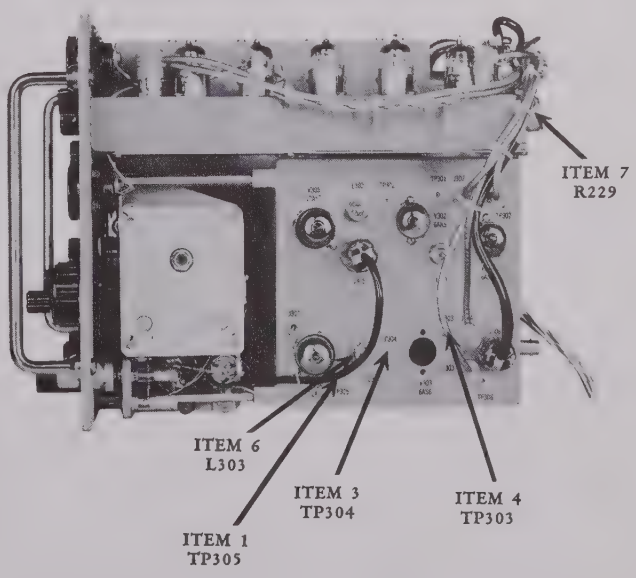


FIGURE 6 (RIGHT SIDE VIEW)

(7) A tone of approximately 100 cps should be heard in headphones if the 100KC divider is properly adjusted.

(8) Rotate potentiometer R229 (Item 7, Fig. 6) fully clockwise, then *counter-clockwise* ¼ *turn*.

(9) Loosen locking nut on L203 (Item 5, Fig. 5) and center coil in range over which tone is heard. A range of ½ turn is normal. Tighten locking nut.

(10) Disconnect Short of step 1 and remove connections of step 6.

(11) Rotate LFO slowly through entire dial range. If the 10KC divider is properly functioning, clean zero beats should be heard every 5KC.

(12) Set LFO dial to 0,5.0.

(13) Loosen locking nut on L303 (Item 6, Fig. 6) and adjust coil for zero beat or low audio tone. The correct setting will provide approximately ½ to ¾ turn of control.

Re-check entire LFO dial for presence of zero beats every 5KC on dial.

(14) Center L303 in range over which proper zero beats are heard. Tighten locking nut.

INABILITY TO ADJUST DIVIDERS AS ABOVE INDICATES COMPONENT FAILURE.

NOTES

SECTION VI
PARTS LIST

HIGH FREQUENCY OSCILLATOR CHASSIS

SYM-BOL	DESCRIPTION		MANUFACTURER	PART NO.
C101	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C102	Capacitor, mica	110 pf	Elmenco	DM15E111J
C103	Capacitor, mica	24 pf	Elmenco	DM15E240J
C104	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C105	Capacitor, mica	110 pf	Elmenco	DM15E111J
C106	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C107	Capacitor, var air		G P I	CA3-2
C108	Capacitor, var cer	5-25 pf	G P I	CA6
C109	Capacitor, mica	950 pf	Elmenco	DM19E951J
C110	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C111	Capacitor, mica	110 pf	Elmenco	DM15E111J
C112	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C113	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C114	Capacitor, var cer	5-25 pf	G P I	CA6
C115	Capacitor, ceramic	10 pf	Centralab	TCN10
C116	Capacitor, mica	4300 pf	Elmenco	DM20E432J
C117	Capacitor, ceramic	.001 uf	Erie	861Z5U102Z
C118	Capacitor var air		G P I	CA3-1
C119	Capacitor, ceramic	.001 uf	Erie	861Z5U102Z
C120	Capacitor, var cer	5-25 pf	G P I	CA6
C121	Capacitor, mica	24 pf	Elmenco	DM15E240J
C122	Capacitor, paper	.5 uf	Hopkins Eng.	P52DS
C123	Capacitor, mica	56 pf	Elmenco	DM15E560J
C124	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C125	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C126	Capacitor, mica	110 pf	Elmenco	DM15E111J
C127	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C128	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C129	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C130	Capacitor, var cer	5-25 pf	G P I	CA6
C131	Capacitor, ceramic	10 pf	Centralab	TCN10
C133	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C135	Capacitor, ceramic	39 pf	Erie	831P3K390K
C136	Capacitor, ceramic	.001 uf	Erie	861Z5U102Z
C137	Capacitor, ceramic	.001 uf	Erie	861Z5U102Z
C138	Capacitor, ceramic	.001 uf	Erie	861Z5U102Z
C139	Capacitor, ceramic	.001 uf	Erie	861Z5U102Z
C140	Capacitor, ceramic	.001 uf	Erie	861Z5U102Z
C141	Capacitor, ceramic	.001 uf	Erie	861Z5U102Z
C145	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
CR101	Diode		Hughes	IN95

SYM-BOL	DESCRIPTION		MANUFACTURER	PART NO.
CRC101	Diode, capactior		Hughes	HC7001
J101-105	Connector, recp. 5 Reqd		G P I	SPM1
J106	Connector, recp.		Amphenol	126-219
L101	Choke	4.7 uh	Miller	6081-4-7
L102	Coil var		G P I	LS25-4
L103	Coil var		G P I	LS25-1
L104	Choke	10 uh	Miller	6081-10
L105	Choke	3.9 uh	Miller	6081-3-9
L106	Choke	3.9 uh	Miller	6081-3-9
L107	Choke	3.9 uh	Miller	6081-3-9
L108	Choke	3.9 uh	Miller	6081-3-9
R101	Resistor, comp.	10K 10% ½W		
R103	Resistor, comp.	10K 10% ½W		
R104	Resistor, comp.	10K 10% ½W		
R105	Resistor, comp.	4.7K 10% ½W		
R106	Resistor, comp.	1M 10% ½W		
R107	Resistor, comp.	220K 10% ½W		
R108	Resistor, comp.	4.7K 10% ½W		
R109	Resistor, comp.	220K 10% ½W		
R110	Resistor, comp.	47 ohms 10% ½W		
R111	Resistor, comp.	100 ohms 10% ½W		
R112	Resistor, comp.	47K 10% ½W		
R113	Resistor, comp.	4.7K 10% ½W		
R114	Potentiometer	1M	G P I	RV12
R115	Resistor, comp.	150K 10% ½W		
R116	Resistor, comp.	82K 10% ½W		
R117	Resistor, comp.	680K 10% ½W		
R118	Resistor, comp.	68K 10% ½W		
R119	Resistor, comp.	100 ohms 10% ½W		
R120	Resistor, comp.	47K 10% ½W		
R121	Resistor, comp.	4.7K 10% ½W		
R122	Resistor, comp.	2.2K 10% ½W		
R123	Resistor, comp.	22K 10% ½W		
R124	Resistor, comp.	100 ohms 10% ½W		
R125	Resistor, comp.	330 ohms 10% ½W		
R126	Resistor, comp.	47K 10% ½W		
R127	Resistor, comp.	2.7K 10% ½W		
R128	Resistor, comp.	270 ohms 10% ½W		
R129	Resistor, comp.	100K 10% ½W		
R132	Resistor, comp.	6.8K 10% ½W		
T101	Transformer		G P I	LS25-3
T102	Transformer		G P I	LS25-5
T103	Transformer		G P I	LS25-2
V101	Electron tube			6AS6
V102	Electron tube			6AK5

SYM-BOL	DESCRIPTION		MANUFACTURER	PART NO.
V103	Electron tube			6AK5
V104	Electron tube			6DK6
V105	Electron tube			6AK5
XV101-105	Socket tube 5 reqd.		Cinch	53C24761

100KC SELECTOR CHASSIS

C201	Capacitor, mica	2200 pf	Elmenco	DM19E222J
C202	Capacitor, mica	1300 pf	Elmenco	DM19E132J
C203	Capacitor, mica	2000 pf	Elmenco	DM19E202J
C204	Capacitor, mica	130 pf	Elmenco	DM15E131J
C205	Capacitor, mica	82 pf	Elmenco	DM15E820J
C206	Capacitor, ceramic	.01 uf	Erie	851Z5U103Z
C207	Capacitor, ceramic	.1 uf	Erie	827Z5V104P
C208	Capacitor, ceramic	.1 uf	Erie	827Z5V104P
C209-C218	5 trimmers per assy. 2 reqd. Capacitor, var. mica	1.5-20 pf	G P I	CM3
C219	Capacitor, ceramic	2.2 pf	Centralab	TCZ2-2
C220	Capacitor, ceramic	3.3 pf	Centralab	TCZ3-3
C221	Capacitor, ceramic	4.7 pf	Centralab	TCZ4-7
C222	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C223	Capacitor, mica	220 pf	Elmenco	DM15E221J
C224	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C225	Capacitor, ceramic	.01 uf	Erie	851Z5U103Z
C226	Capacitor, ceramic	.02 uf	Erie	811Z5V203Z
C227	Capacitor, mica	110 pf	Elmenco	DM15E111J
C228	Capacitor, mica	2000 pf	Elmenco	DM19E202J
C229-C238	5 trimmers per assy. 2 reqd. Capacitor, var. mica	1.5-20 pf	G P I	CM3
C239	Capacitor, ceramic	2.2 pf	Centralab	TCZ2-2
C240	Capacitor, ceramic	3.3 pf	Centralab	TCZ3-3
C241	Capacitor, ceramic	4.7 pf	Centralab	TCZ4-7
C242	Capacitor, mica	110 pf	Elmenco	DM15E111J
C243	Capacitor, ceramic	.001 uf	Erie	861Z5U102Z
C244	Capacitor, ceramic	.01 uf	Erie	851Z5U103Z
C245	Capacitor, ceramic	.01 uf	Erie	851Z5U103Z
C246-C255	5 trimmers per assy. 2 reqd. Capacitor, var. mica	1.5-20 pf	G P I	CM3
C256	Capacitor, mica	110 pf	Elmenco	DM15E111J
C257	Capacitor, ceramic	.01 uf	Erie	851Z5U103Z
C258	Capacitor, ceramic	.01 uf	Erie	851Z5U103Z
C259	Capacitor, ceramic	.01 uf	Erie	851Z5U103Z
C260-C269	5 trimmers per assy. 2 reqd. Capacitor, var. mica	1.5-20 pf	G P I	CM3
C270	Capacitor, ceramic	.001 uf	Erie	861Z5U102Z
C271	Capacitor, mica	110 pf	Elmenco	DM15E111J
C272	Capacitor, ceramic	.01		851Z5U103Z

SYM-BOL	DESCRIPTION		MANUFACTURER	PART NO.
CR201	Diode		Transitron	IN273
CR202	Diode		Transitron	IN273
CR203	Diode		Transitron	IN273
CR204	Diode		Texas Inst.	IN457
CR205	Diode		Texas Inst.	IN457
CR206	Diode		Hughes	IN459
CR207	Diode		Hughes	IN95
J201-J206	Connector, recp. 6 Reqd.		G P I	SPM1
J207	Connector, recp.		Amphenol	126-219
L201	Choke		G P I	LS26
L202	Choke	10 uh	Miller	70F105AI
L203	Coil var		G P I	LS25-6
L204	Coil var		G P I	LS25-7
L205	Coil, var		G P I	LS25-7
L206	Coil, var		G P I	LS25-9
R201	Resistor, comp.	Factory selected (470 ohms 10% ½W nom)		
R202	Resistor, comp.	1K 10% ½W		
R203	Resistor, comp.	47K 10% ½W		
R204	Resistor, comp.	470 ohms 10% ½W		
R205	Resistor, comp.	22K 10% ½W		
R206	Resistor, comp.	4.7K 10% ½W		
R207	Resistor, comp.	22K 10% ½W		
R208	Resistor, comp.	1.5K 10% ½W		
R209	Resistor, comp.	100K 10% ½W		
R210	Resistor, comp.	27 ohms 10% ½W		
R211	Resistor, comp.	2.2K 10% ½W		
R212	Resistor, comp.	2.2K 10% ½W		
R213	Resistor, comp.	4.7K 10% ½W		
R214	Resistor, comp.	2.2K 10% ½W		
R215	Resistor, comp.	100 ohms 10% ½W		
R216	Resistor, comp.	1K 10% ½W		
R217	Resistor, comp.	100K 10% ½W		
R218	Resistor, comp.	47K 10% ½W		
R219	Resistor, comp.	39K 10% ½W		
R220	Resistor, comp.	2.2K 10% ½W		
R221	Resistor, comp.	220 ohms 10% ½W		
R222	Resistor, comp.	15K 10% ½W		
R223	Resistor, comp.	2.2K 10% ½W		
R224	Resistor, comp.	220K 10% ½W		
R225	Resistor, comp.	4.7K 10% ½W		
R226	Resistor, comp.	220 ohms 10% ½W		
R227	Resistor, comp.	22K 10% ½W		
R228	Resistor, comp.	2.2K 10% ½W		
R229	Rheostat, ww	3K with 100 ohm stop	Mel Rain	104
R230	Resistor, comp.	220K 10% ½W		

SYMBOL	DESCRIPTION		MANUFACTURER	PART NO.
R232	Resistor, comp.	4.7K 10% ½W		
R233	Resistor, comp.	10K 10% ½W		
S201	Switch		GPI	SW11
T201	Transformer		GPI	LS25-10
TP201-TP204	Jack, test 4 Reqd.		Sealectro	SKT5BC
V201	Electron, tube			6AS6
V202	Electron, tube			6AN4
V203	Electron, tube			6AK5
V204	Electron, tube			6AS6
V205	Electron, tube			6AK5
XV201-XV205	Socket, tube 5 Reqd.		Cinch	53C24761

PHASE DISCRIMINATOR CHASSIS

C301	Capacitor, ceramic	.001 uf	Erie	861Z5U102Z
C302	Capacitor, ceramic	.01 uf	Erie	851Z5U103Z
C304	Capacitor, ceramic	.1 uf	Erie	827Z5V104P
C305	Capacitor, mica	220 pf	Elmenco	DM15E221J
C306	Capacitor, mica	430 pf	Elmenco	DM15E431J
C307	Capacitor, ceramic	.1 uf	Erie	827Z5V104P
C308	Capacitor, mica	220 pf	Elmenco	DM15E221J
C309	Capacitor, ceramic	.1 uf	Erie	827Z5V104P
C310	Capacitor, ceramic	.1 uf	Erie	827Z5V104P
C311	Capacitor, ceramic	.001 uf	Erie	861Z5U102Z
C312	Capacitor, ceramic	15 pf	Centralab	TCZ15
C313	Capacitor, ceramic	20 pf	Centralab	TCZ20
C314	Capacitor, ceramic	15 pf	Centralab	TCZ15
C315	Capacitor, ceramic	.01 uf	Erie	851Z5U103Z
C316	Capacitor, mica	110 pf	Mica	DM15E111J
C317	Capacitor, mica	110 pf	Mica	DM15E111J
C318	Capacitor, ceramic	.01 uf	Erie	851Z5U103Z
C319	Capacitor, elect	15 uf	Fansteel	PP15B15A2
C322	Capacitor, plastic	.015 uf	Goodall	663UW-015UF200V
C323	Capacitor, mica	4300 pf	Elmenco	DM20E432J
C325	Capacitor, ceramic	.005 uf 20%	Erie	851Z5U502M
C326	Capacitor, mica	150 pf	Elmenco	DM15E151J
C327	Capacitor, ceramic	.005 uf 20%	Erie	851Z5U502M
C328	Capacitor, mica	110 pf	Elmenco	DM15E111J
C329	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C330	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C331	Capacitor, paper	.25 uf	Hopkins Eng.	P252D
C332	Capacitor, ceramic	.1 uf	Erie	827Z5V104P
C333	Capacitor, ceramic	.001 uf	Erie	861Z5U102Z
C335	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C336	Capacitor, mica	56 pf	Elmenco	DM15E560J
C337	Capacitor, ceramic	.001 uf	Erie	861Z5U102Z

SYM-BOL	DESCRIPTION		MANUFACTURER	PART NO.
C338	Capacitor, elect	15 uf	Sprague	TE1129
C339	Capacitor, ceramic	.001 uf	Erie	861Z5U102Z
C340	Capacitor, ceramic	.01 uf	Erie	851Z5U103Z
CR301-CR304	Diode 4 reqd.		Hughes	1N95
CR305	Diode		Transitron	1N273
CR306	Diode		Interntl Rect.	1N1510
J301-J304	Connector, recp. 4 reqd.		GPI	SPM1
J305	Connector, recp.		Amphenol	126-219
J306	Connector, recp.		Amphenol	126-221
J307	Connector, recp.		GPI	SPM1
J308	Connector, recp.			UG657U
L301	Coil, var		GPI	LS25-17
L302	Coil, var		GPI	LS25-15
L303	Coil, var		GPI	LS25-17
L304	Choke	5 mh	GPI	LS7
Q301-Q303	Transistor		Amperex	ME216
R301	Resistor, comp.	6.8K 10% ½W		
R302	Resistor, comp.	100K 10% ½W		
R303	Resistor, comp.	82K 10% ½W		
R304	Resistor, comp.	22K 10% ½W		
R305	Resistor, comp.	470 ohms 10% ½W		
R306	Resistor, comp.	27K 10% ½W		
R307	Resistor, comp.	2.2K 10% ½W		
R308	Resistor, comp.	2.2K 10% ½W		
R309	Resistor, comp.	22K 10% ½W		
R310	Resistor, comp.	27K 10% ½W		
R311	Resistor, comp.	22K 10% ½W		
R312	Resistor, comp.	470 ohms 10% ½W		
R313	Resistor, comp.	82K 10% ½W		
R314	Resistor, comp.	47K 10% ½W		
R315	Resistor, comp.	150K 10% ½W		
R316	Resistor, comp.	150K 10% ½W		
R317	Resistor, comp.	47K 10% ½W		
R318	Resistor, comp.	47K 10% ½W		
R319	Resistor, comp.	47K 10% ½W		
R326	Resistor, comp.	100K 10% ½W		
R327	Resistor, comp.	22K 10% ½W		
R328	Resistor, comp.	22K 10% ½W		
R330	Resistor, comp.	22K 10% ½W		
R331	Resistor, comp.	12K 10% ½W		
R332	Resistor, comp.	470 ohms 10% ½W		
R333	Resistor, comp.	22K 10% ½W		
R334	Resistor, comp.	1M 10% ½W		
R335	Resistor, comp.	47K 10% ½W		

SYMBOL	DESCRIPTION		MANUFACTURER	PART NO.
R336	Resistor, comp.	220K 10% ½W		
R337	Resistor, comp.	22K 10% ½W		
R338	Resistor, comp.	470 ohms 10% ½W		
R339	Resistor, comp.	22K 10% ½W		
R340	Resistor, comp.	470 ohms 10% ½W		
R341	Resistor, comp.	220K 10% ½W		
R342	Resistor, comp.	4.7K 10% ½W		
R343	Resistor, comp.	2.2K 10% ½W		
R345	Resistor, comp.	22K 10% ½W		
R348	Resistor, comp.	1K 10% ½W		
R349	Resistor, comp.	4.7K 10% ¼W		
R350	Resistor, comp.	220K 10% ¼W		
R351	Resistor, comp.	15K 10% ¼W		
R352	Resistor, comp.	1K 10% ¼W		
R353	Resistor, comp.	47K 10% ¼W		
R354	Resistor, comp.	15K 10% ¼W		
R355	Resistor, comp.	680 ohms 10% ¼W		
R356	Resistor, comp.	4.7K 10% ¼W		
R357	Resistor, comp.	22K 10% 2W		
TP301 TP302 TP304 TP305 TP308	Jack, test 5 Reqd.		Sealectro	SKT5BC
V301	Electron tube			6AS6
V302	Electron tube			6AK5
V304	Electron tube			12AT7
V305	Electron tube			12AY7
XV301 XV302	Socket tube 2 reqd.		Cinch	53C24761
XV304	Socket tube		Cinch	44F24760
XV305	Socket tube		Cinch	44F24760

LOW FREQUENCY OSCILLATOR CHASSIS

C401	Capacitor, var air		G P I	AA229
C402	Capacitor, var quartz		JFD Electronics	VCJ138
C403	Capacitor, var quartz		JFD Electronics	VC11
C404	Capacitor, mica	1000 pf	Elmenco	DM19E102J
C405	Capacitor, mica	1000 pf	Elmenco	DM19E102J
C406	Capacitor, ceramic	.1 uf	Erie	827Z5V104P
C407	Capacitor, ceramic	.01 uf	Erie	851Z5U103Z
C408	Capacitor, ceramic	.1 uf	Erie	827Z5V104P
C409	Capacitor, ceramic	20 pf	Centralab	TCZ20
C410	Capacitor, ceramic	22 pf	Centralab	TCN22
I401	Lamp, incandescent		G E	51
J401	Connector, recp.		Amphenol	126-220
L401	Coil		G P I	TS123
P401	Connector, plug		Cinch	13A
R401	Resistor, comp.	2.2K 10% ½W		

SYM-BOL	DESCRIPTION		MANUFACTURER	PART NO.
R402	Resistor, comp.	220K 10% ½W		
R403	Resistor, comp.	100 ohms 10% ½W		
R404	Resistor, comp.	5.6K 10% ½W		
R405	Resistor, comp.	47K 10% ½W		
R406	Resistor, comp.	1K 10% ½W		
R407	Resistor, comp.	1M 10% ½W		
R408	Resistor, comp.	10 ohms 10% 1W		
V401	Electron tube			6BH6
XI401	Socket lamp		G P I	EP1
XV401	Socket tube			TS102C01
	Shield tube		Cinch	TR5-5020B

CRYSTAL OSC. & AUDIO AMP. CHASSIS

C501	Capacitor, ceramic	.001 uf	Erie	861Z5U102Z
C502	Capacitor, ceramic	.001 uf	Erie	861Z5U102Z
C504	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C505	Capacitor, paper	.5 uf	Hopkins Eng.	P52DS
C506	Capacitor, ceramic	.1 uf	Erie	827Z5V104P
C507	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C508	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C509	Capacitor, elect	5 uf	Sprague	TE1504
C510	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C511	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C512	Capacitor, plastic	.05 uf 1%	Goodall	513G50312
C513	Capacitor, ceramic	.1 uf	Erie	827Z5V104P
C514	Capacitor, mica	82 pf	Elmenco	DM15E820J
C517	Capacitor, ceramic	.01 uf	Erie	851Z5U103Z
C518	Capacitor, ceramic	.01 uf	Erie	851Z5U103Z
C519	Capacitor, ceramic	.01 uf	Erie	851Z5U103Z
C521	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C522	Capacitor, mica	110 pf	Elmenco	DM15E111J
C524	Capacitor, ceramic	.01 uf	Erie	851Z5U103Z
C525	Capacitor, ceramic	.01 uf	Erie	851Z5U103Z
C526	Capacitor, ceramic	.005 uf	Erie	801Z5U502Z
C528	Capacitor, mica	620 pf	Elmenco	DM15E621J
C529	Capacitor, ceramic	.01 uf	Erie	851Z5U103Z
C530	Capacitor, var cer	5-25 pf	G P I	CA7
C531	Capacitor, var cer	5-25 pf	G P I	CA7
C532	Capacitor, mica	620 pf	Elmenco	DM15E621J
C533	Capacitor, ceramic	.05 uf	Gulton Ind.	MINO-05Z75V
C534	Capacitor, elect	5 uf	Sprague	TE1504
C535	Capacitor, mica	33 pf	Elmenco	DM15E330J
C536-C539	Capacitor, mica 4 reqd.	33 pf	Elmenco	DM15E330J
CR501	Diode		G E	IN3604
CR502	Diode		Transitron	IN273
CR503	Diode		Hughes	IN95

SYMBOL	DESCRIPTION		MANUFACTURER	PART NO.
J501-J503	Connector, recp. 3 reqd		GPI	SMP1
J504	Jack phone		Swithcraft	11
J505	Connector, recp.		GPI	SPM1
J506	Connector, recp.		Winchester	M12PLS12N
J507	Connector, recp.			UG657U
L501	Inductor .5H		Triad	EM500
R501	Resistor, comp.	10K 10% ½W		
R502	Resistor, comp.	47 ohms 10% ½W		
R503	Resistor, comp.	10K 10% ½W		
R505	Resistor, comp.	100K 10% ½W		
R506	Resistor, comp.	100K 10% ½W		
R507	Resistor, comp.	10M 10% ½W		
R508	Resistor, comp.	220K 10% ½W		
R509	Resistor, comp.	470K 10% ½W		
R510	Resistor, comp.	10M 10% ½W		
R511	Resistor, comp.	150K 10% ½W		
R512	Resistor, comp.	10K 10% ½W		
R513	Resistor, comp.	10K 10% ½W		
R514	Resistor, comp.	270 ohms 10% ½W		
R515	Resistor, comp.	1M 10% ½W		
R516	Resistor, comp.	150K 10% ½W		
R517	Resistor, comp.	10K 10% ½W		
R520	Resistor, comp.	15K 10% ½W		
R523	Rheostat WW	1K	Mel Rain	106
R524	Resistor, comp.	100K 10% ½W		
R525	Resistor, comp.	47 ohms 10% ½W		
R528	Resistor, comp.	4.7K 10% ½W		
R529	Potentiometer	25K	GPI	RV23
R530	Resistor, comp.	68K 10% ½W		
R531	Potentiometer	150K	Bourns	215L1-154
R532	Resistor, comp.	4.7K 10% ½W		
R533	Resistor, comp.	220K 10% ½W		
R534	Resistor, comp.	22K 10% ½W		
R535	Resistor, comp.	10K 10% ½W		
R536	Resistor, comp.	150K 10% ½W		
R537	Resistor, comp.	47 ohms 10% ½W		
R538	Resistor, comp.	1M 10% ½W		
R539	Resistor, comp.	100K 10% ½W		
R540	Resistor, comp.	2.2K 10% ½W		
R541	Resistor, comp.	1M 10% ½W		
R542	Resistor, comp.	39K 10% ½W		
R543	Resistor, comp.	47K 10% ½W		
R544	Resistor, comp.	2.2K 10% ½W		
R545	Resistor, comp.	47K 10% ½W		
R546	Resistor, comp.	1.8K 10% ½W		

SYM-BOL	DESCRIPTION		MANUFACTURER	PART NO.
R547	Rheostat WW	1K	Mel Rain	106
R548	Resistor, comp.	100K 10% ½W		
R549	Resistor, comp.	220K 10% ½W		
R550	Resistor, comp.	10K 10% ½W		
R551	Resistor, comp.	4.7K 10% ½W		
R552	Potentiometer	150K	Bourns	215L1-154
S501	Switch		G P I	SW32
T501	Transformer		G P I	TP3
T502	Transformer		G P I	LS25-16
V501	Electron tube			12AX7
V502	Electron tube			12AT7
V503	Electron tube			6AK5
V504	Electron tube			6AK5
V505	Electron tube			12AT7
XV501	Socket tube		Cinch	44F24760
XV502	Socket tube		Cinch	44F24760
XV503	Socket tube		Cinch	53C24761
XV504	Socket tube		Cinch	53C24761
XV505	Socket tube		Cinch	44F24760
XY501	Socket tube		Cinch	51B16759
Y501	Crystal, assy.		G P I	YC3

POWER SUPPLY CHASSIS

C601	Capacitor, elect	3X20uf450V	Aerovox	AEP444J
C602	Capacitor, ceramic	.01 uf	Erie	851Z5U103Z
C603	Capacitor, ceramic	.1 uf	Erie	827Z5V104P
CR601-CR604	Diode 4 reqd.		Diodes Inc.	DI56
F601	Fuse for 115V operation		Bussmann	MDL1
F601	Fuse for 230V operation		Bussmann	MDL1-2
FL601	Filter (OPTIONAL)		Filtron	FA6902
J601	Connector, recp.		Tower	H10610A
J602	Connector, recp.		Winchester	M12SLS12N
J603	Connector, recp.		Tower	H10610A
R601	Resistor WW	4K 15W	Truohm	MOR15-4K
R602	Resistor comp.	1K 10% ½W		
R603	Resistor comp.	10 ohms 10% ½W		
R604	Resistor comp.	10 ohms 10% ½W		
R605	Resistor comp.	1K 10% ½W		
R606	Resistor comp.	470K 10% ½W		
R607	Resistor comp.	120K 10% ½W		
R608	Resistor comp.	15K 10% ½W		
R609	Resistor WW	7.5K 5W	Ward Leonard	5X7-5K
R610	Potentiometer	100K	Allen Bradley	JLU1041
R611	Resistor, comp.	220K 10% ½W		
R612	Resistor comp.	220K 10% ½W		

SYM-BOL	DESCRIPTION	MANUFACTURER	PART NO.
T601	Transformer	G P I	TP4
V601	Electron tube		6BX7
V602	Electron tube		6AK5
V603	Electron tube		OC2
XC601	Socket tube	Cinch	51B16758
XF601	Fuseholder	Littelfuse	342004
XV601	Socket tube	Cinch	51B16758
XV602	Socket tube	Cinch	53C24761
XV603	Socket tube	Cinch	53C24761
	PANEL - FRONT		
J701	Connector, recp.		UG492AU
J702	Connector, recp.		UG657U
M701	Meter tune max	G P I	ME5MA6
M702	Meter tune max	G P I	ME5MA6
M703	Meter zero center	G P I	ME6
M704	Meter zero center	G P I	ME6
S701	Switch	G P I	SW33
W701	Inter-connecting cable	G P I	DI177
W702	Power cable	Belden	KH3385
WP702	Adapter plug	Cornish	228
	Knob 1 required	Johnson	116-220-2
	Knob 3 required	Johnson	116-224-2
	Knob 2 required	Johnson	116-266-2
	Knob 1 required	National	HRP

SUBSTITUTIONS: When expedient, equivalent components may be substituted at the factory. Performance will not be impaired. When making replacements; either parts in this list or the substituted equivalent may be used.

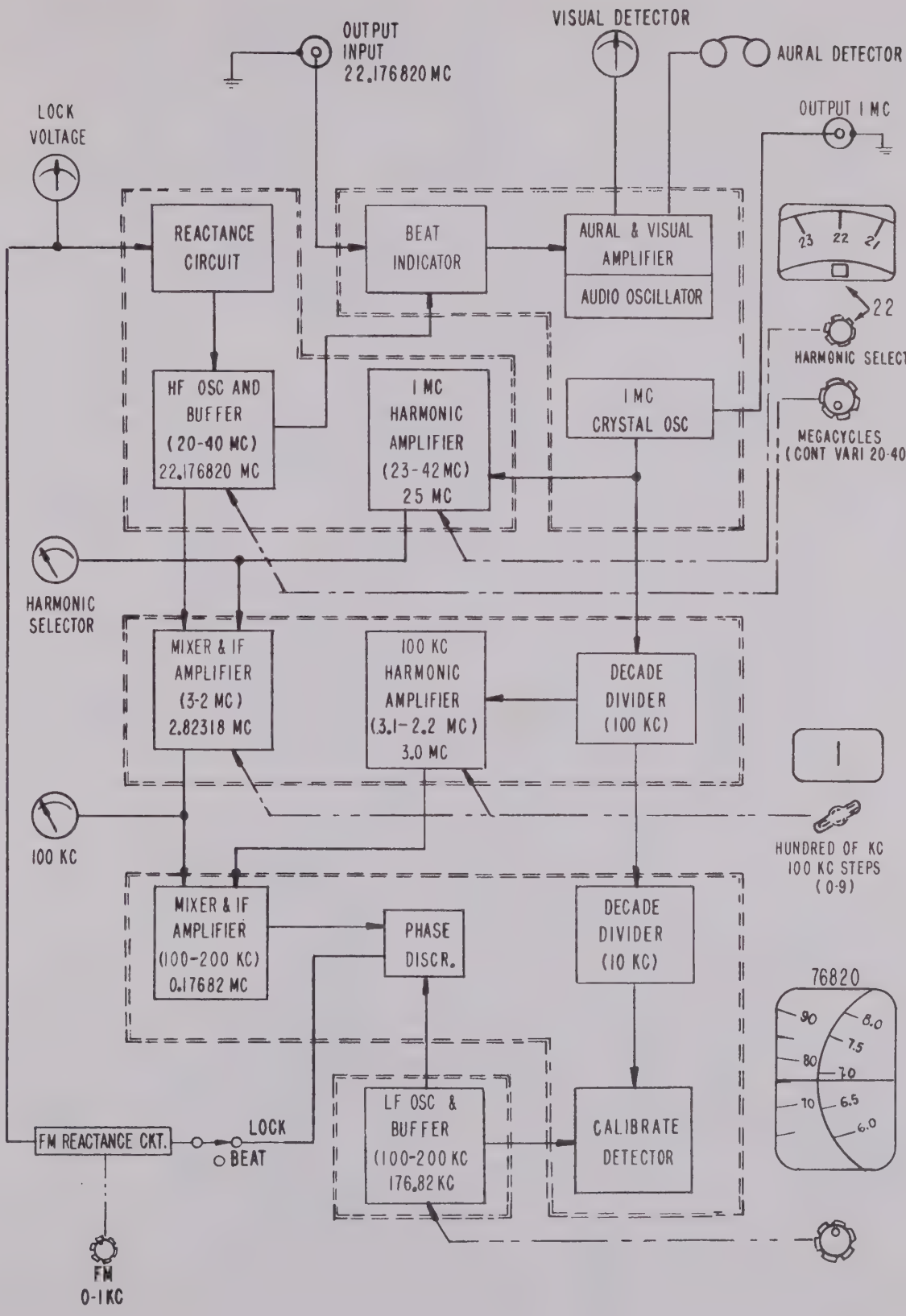


FIGURE 7 — BLOCK DIAGRAM

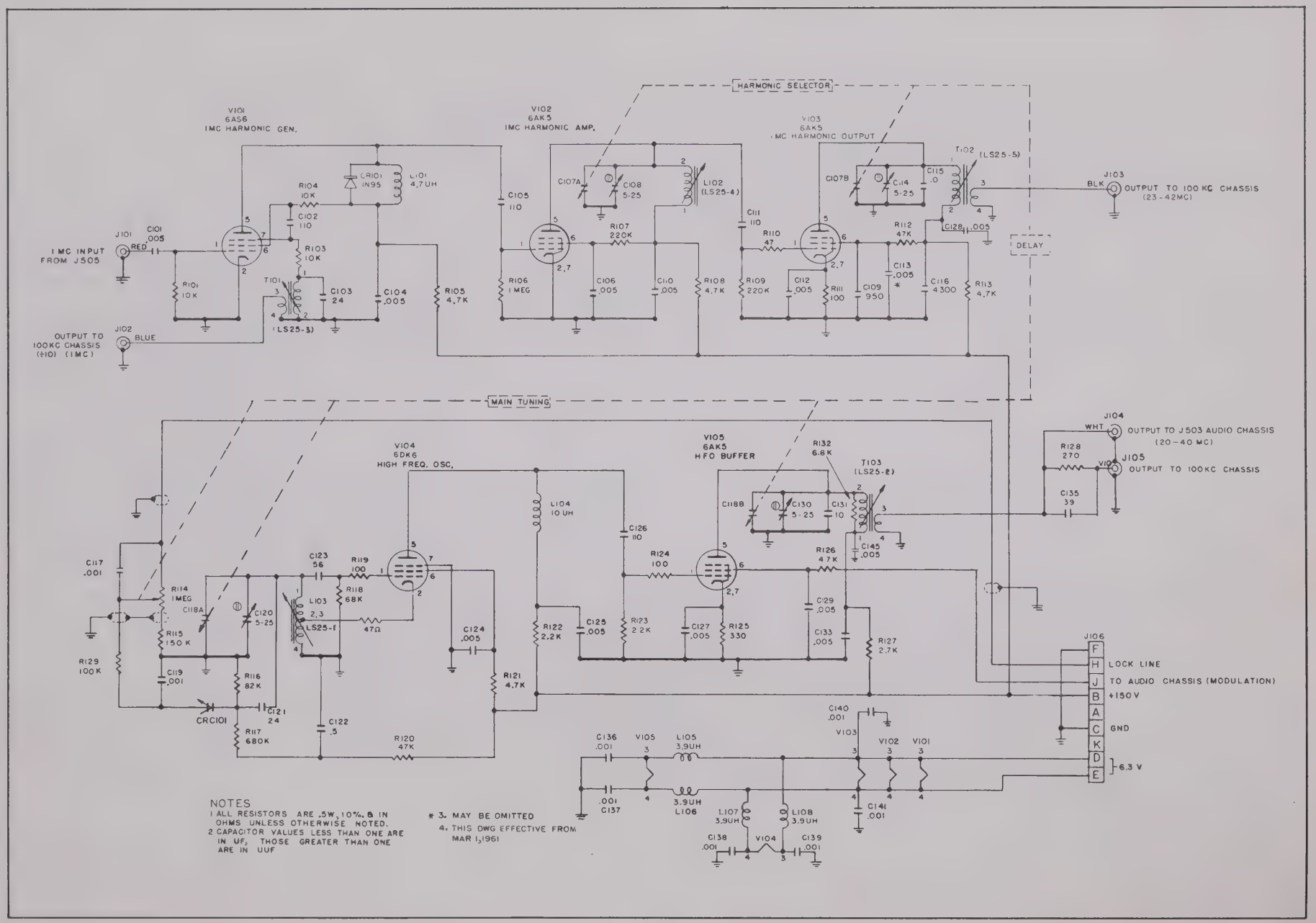
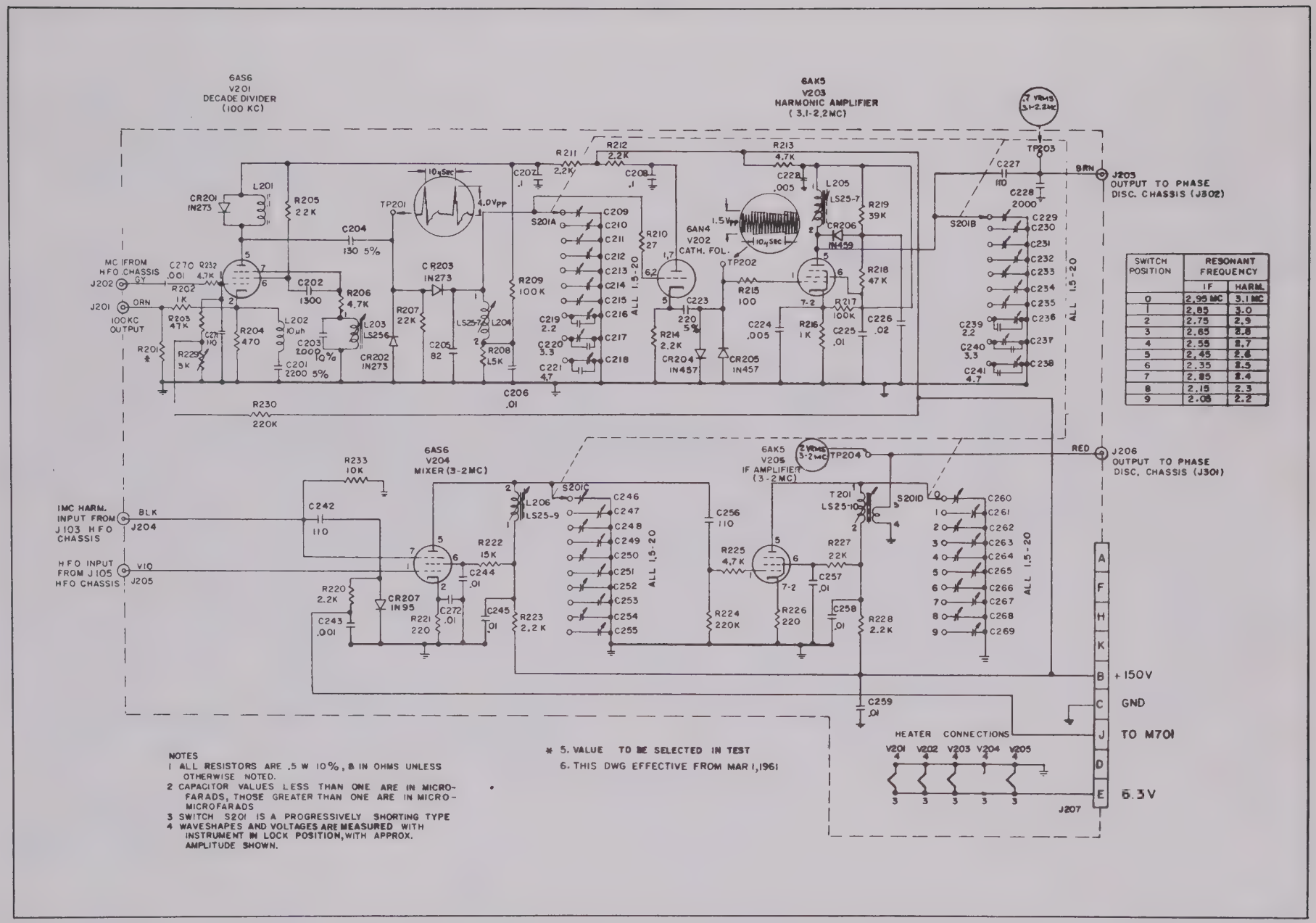


FIGURE 8 — HIGH FREQUENCY OSCILLATOR CHASSIS



SWITCH POSITION	RESONANT FREQUENCY	
	IF	HARM.
0	2.95 MC	3.1 MC
1	2.85	3.0
2	2.75	2.9
3	2.65	2.8
4	2.55	2.7
5	2.45	2.6
6	2.35	2.5
7	2.25	2.4
8	2.15	2.3
9	2.05	2.2

NOTES
1 ALL RESISTORS ARE .5 W 10%, Ω IN OHMS UNLESS OTHERWISE NOTED.
2 CAPACITOR VALUES LESS THAN ONE ARE IN MICROFARADS, THOSE GREATER THAN ONE ARE IN MICRO-MICROFARADS
3 SWITCH S201 IS A PROGRESSIVELY SHORTING TYPE
4 WAVESHAPES AND VOLTAGES ARE MEASURED WITH INSTRUMENT IN LOCK POSITION, WITH APPROX. AMPLITUDE SHOWN.

* 5. VALUE TO BE SELECTED IN TEST
6. THIS DWG EFFECTIVE FROM MAR 1, 1961

FIGURE 9 — 100KC SELECTOR CHASSIS

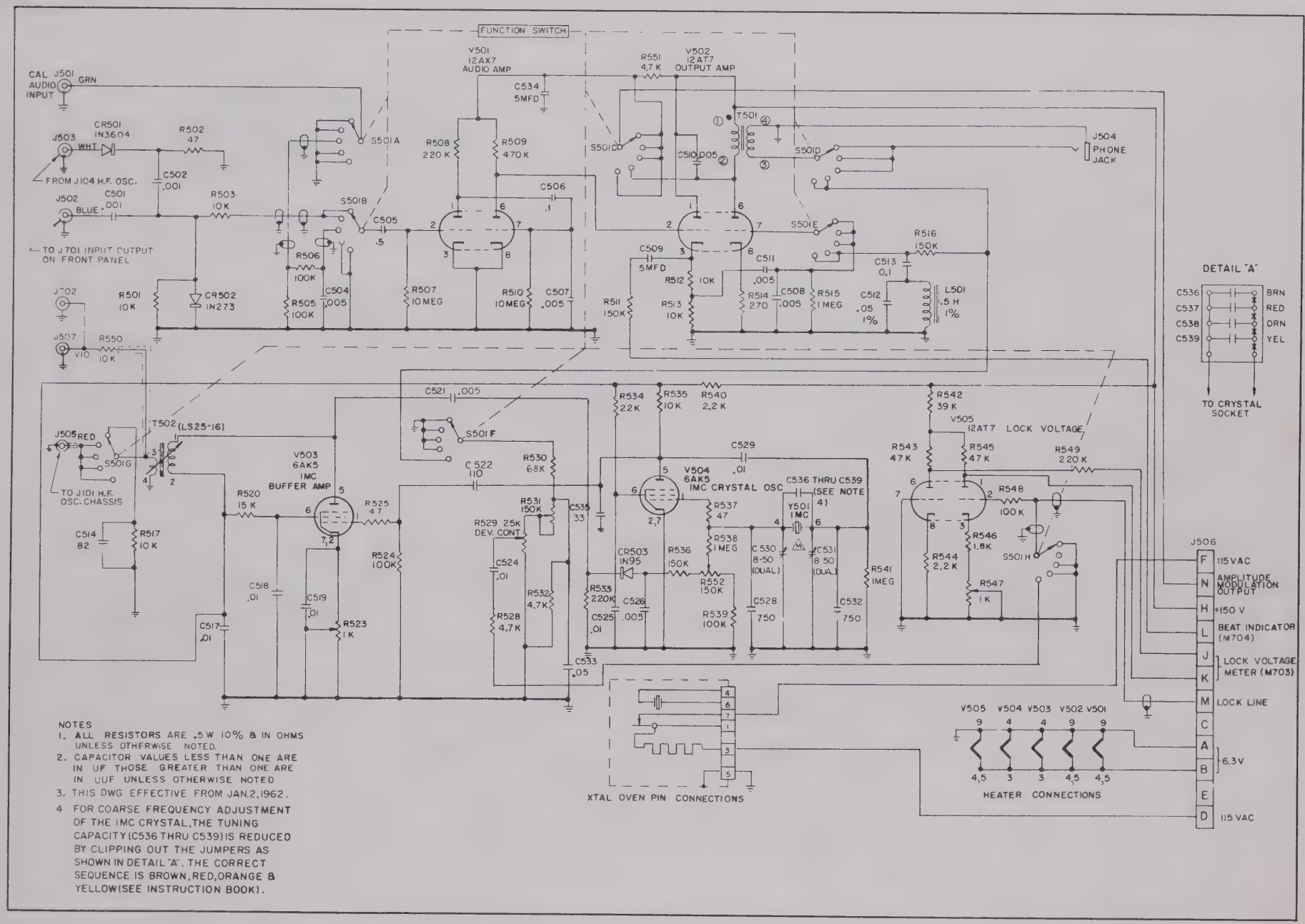


FIGURE 10 — CRYSTAL OSCILLATOR & AUDIO CHASSIS

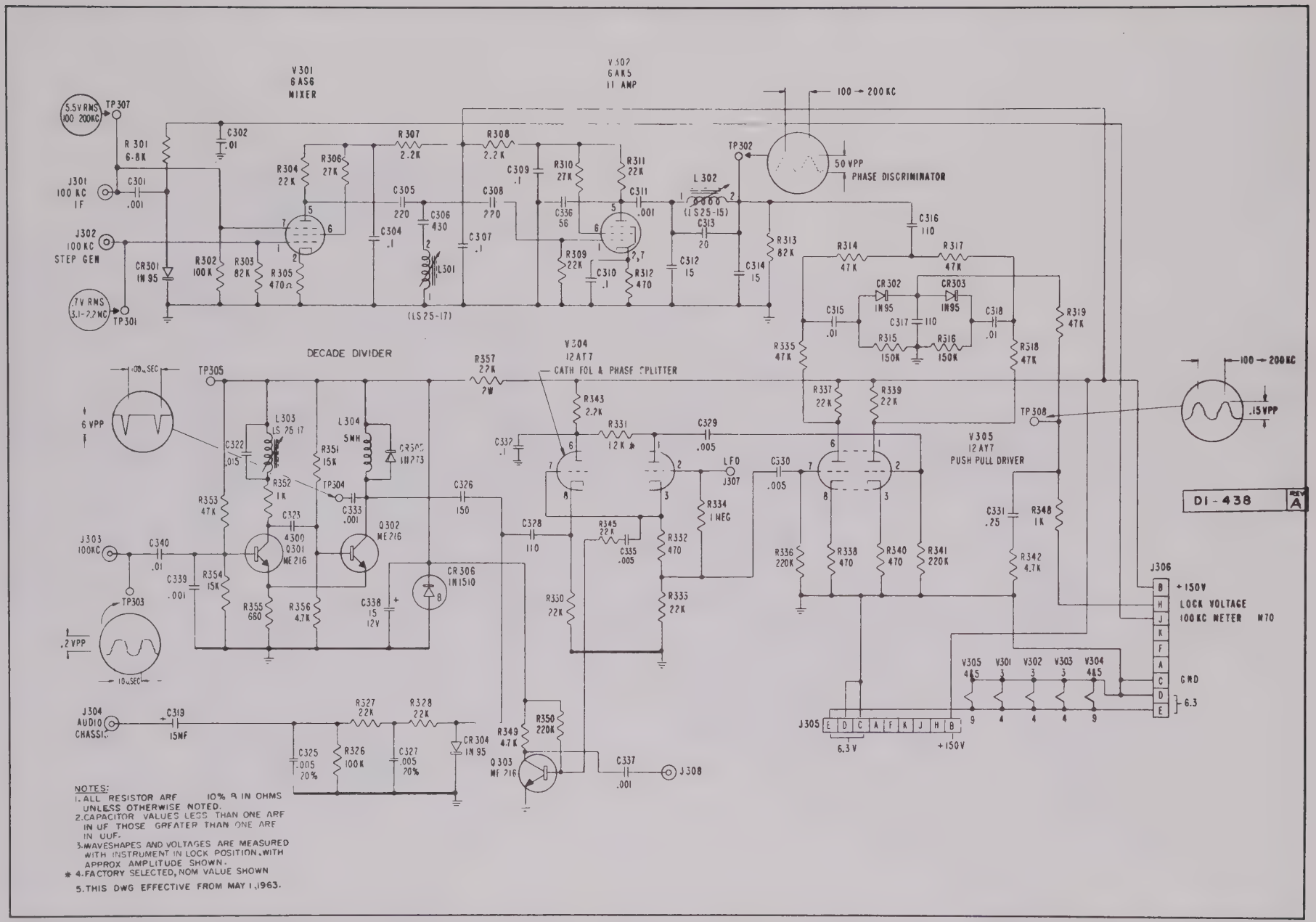
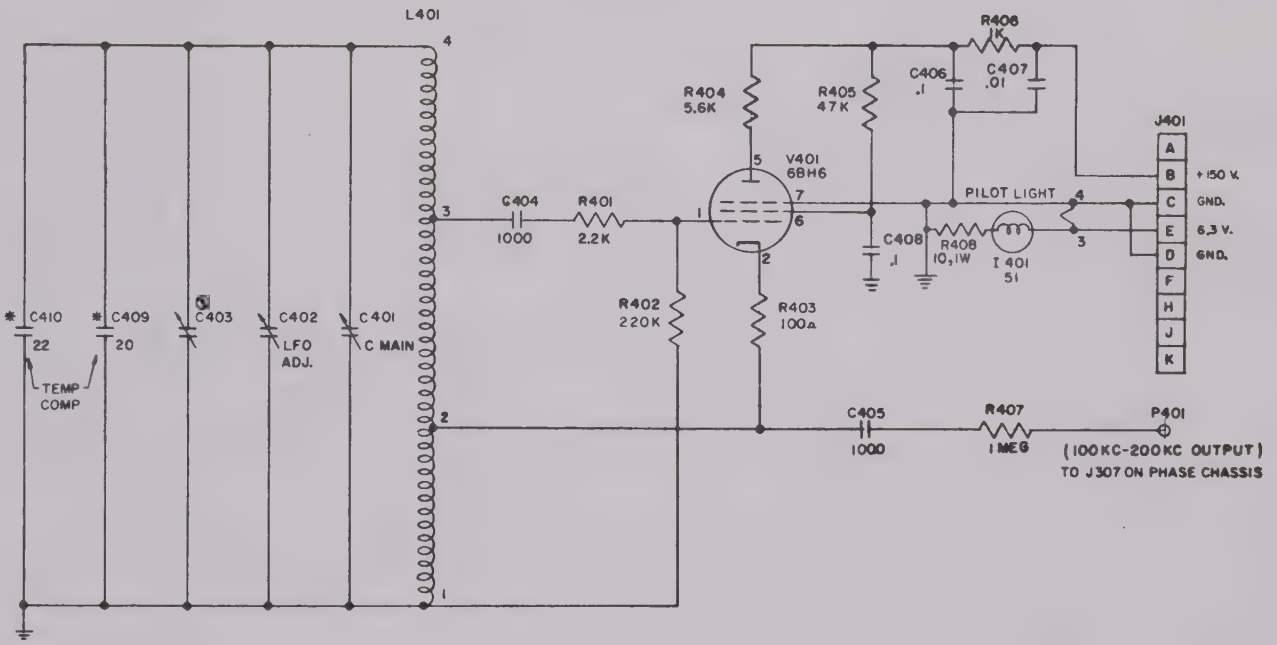
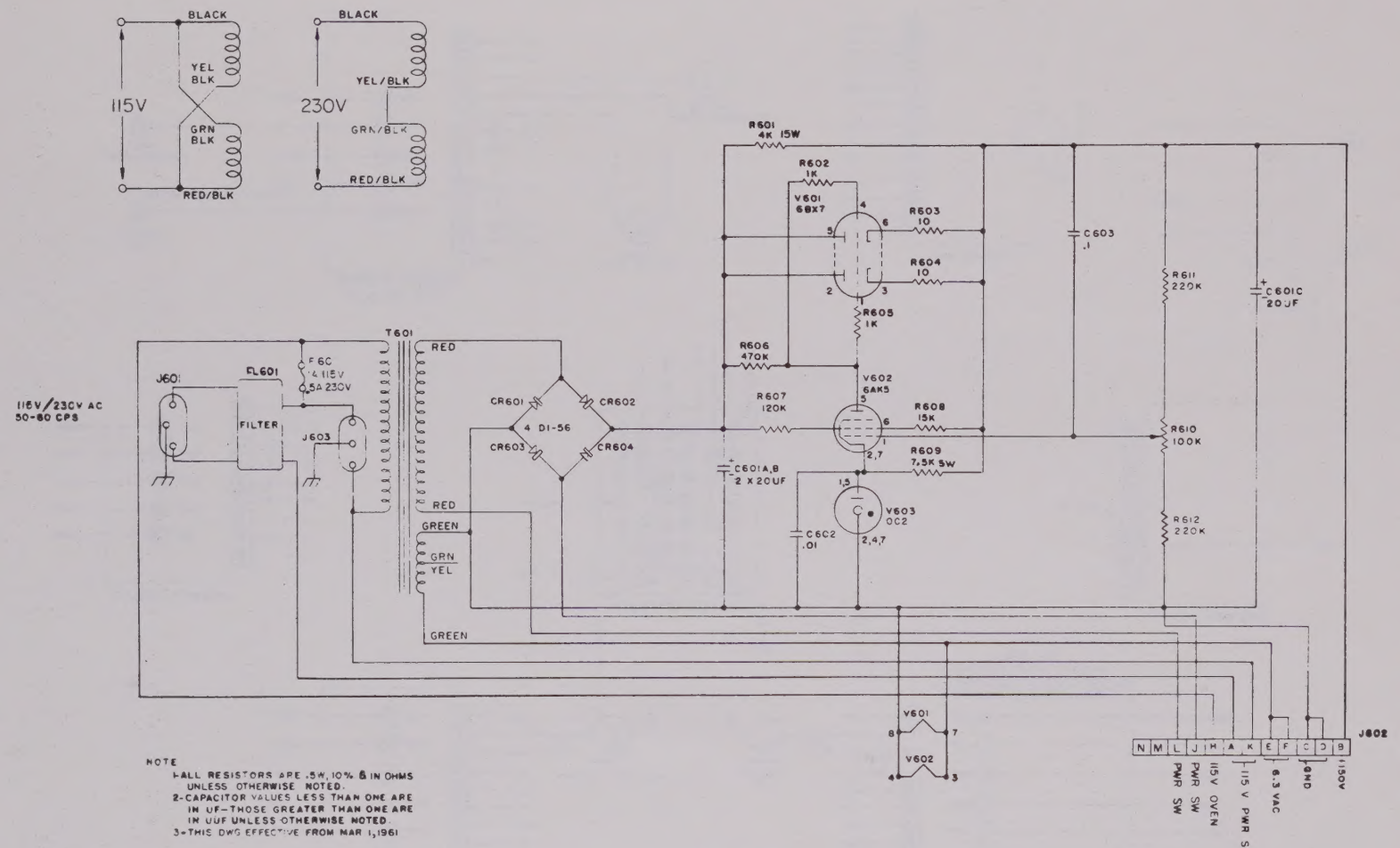


FIGURE 11 — PHASE DISCRIMINATOR CHASSIS



NOTES
1.- ALL RESISTORS ARE .5W 10% 'B IN OHMS UNLESS OTHERWISE NOTED.
2.- CAP. VALUES LESS THAN ONE ARE IN UF — THOSE GREATER THAN ONE ARE IN UUF UNLESS OTHERWISE NOTED.
* 3.- FACTORY SELECTED, NOMINAL VALUE SHOWN.
4.- THIS DWG EFFECTIVE FROM MAR 1, 1961.

FIGURE 12 — LOW FREQUENCY OSCILLATOR CHASSIS



NOTE
1-ALL RESISTORS ARE .5W, 10% & IN OHMS UNLESS OTHERWISE NOTED.
2-CAPACITOR VALUES LESS THAN ONE ARE IN UF-THOSE GREATER THAN ONE ARE IN UUF UNLESS OTHERWISE NOTED.
3-THIS DWG EFFECTIVE FROM MAR 1, 1961

FIGURE 13 — POWER SUPPLY CHASSIS

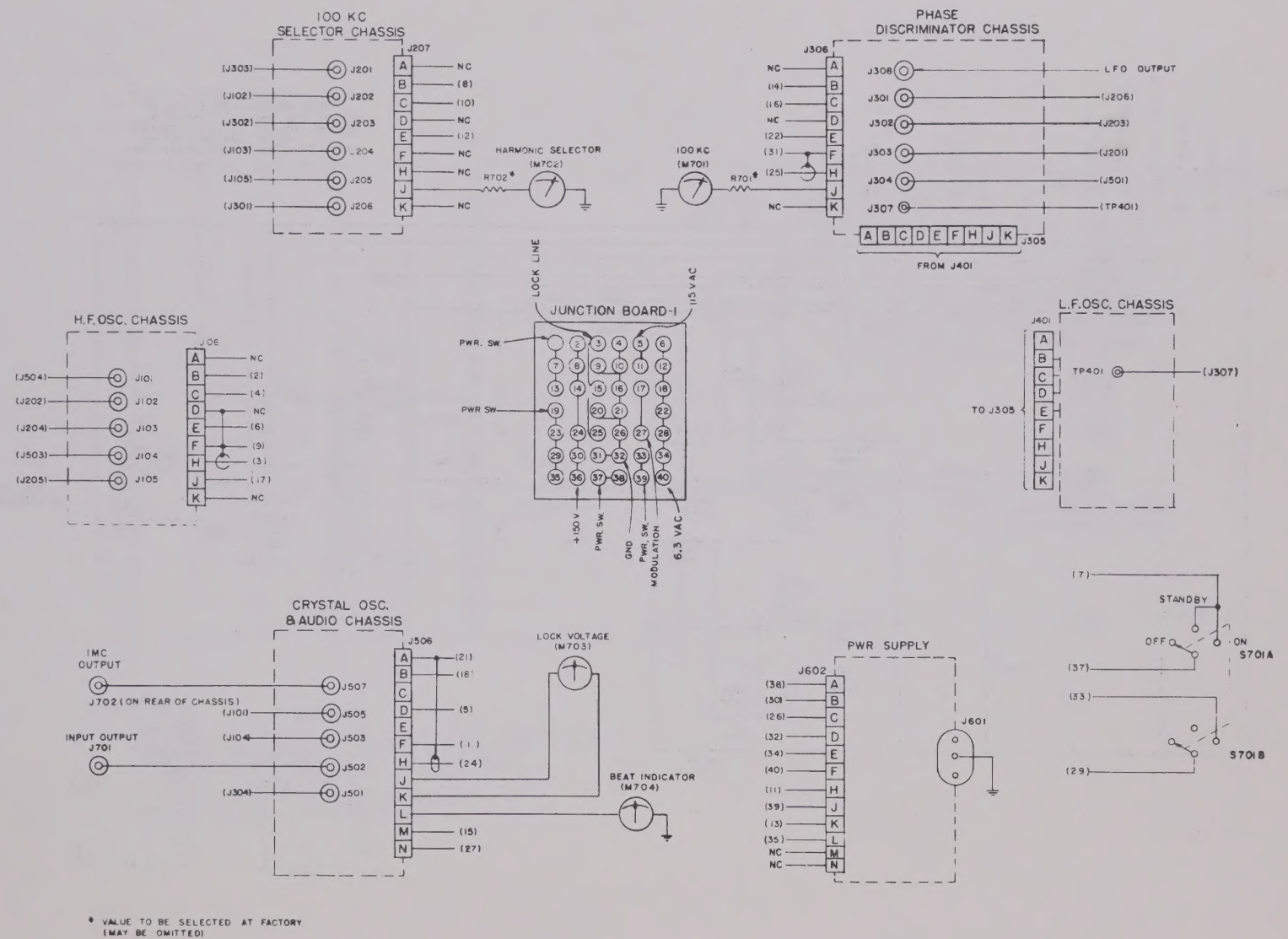


FIGURE 14 — INTERCONNECTING CABLE, BLOCK DIAGRAM